



A user-centred approach to unlock the potential of non-invasive BCIs: an unprecedented international translational effort

Jeunet, C., Bernaroch, C., Cabestaing, F., Chavarriaga, R., Colamarino, E., Corsi, M. C., Coyle, D., De Vico Fallani, F., Enriquez-Geppert, S., Figueiredo, P., Grosse-Wentrup, M., Kleih, S., Kober, S., Kubler, A., Lotte, F., Maby, E., Mattia, D., Mattout, J., Muller-Putz, G., ... Wriessnegger, S. (2020). *A user-centred approach to unlock the potential of non-invasive BCIs: an unprecedented international translational effort*. Abstract from CHIST-ERA CONFERENCE 2020.

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A user-centred approach to unlock the potential of non-invasive BCIs:

An unprecedented international translational effort -

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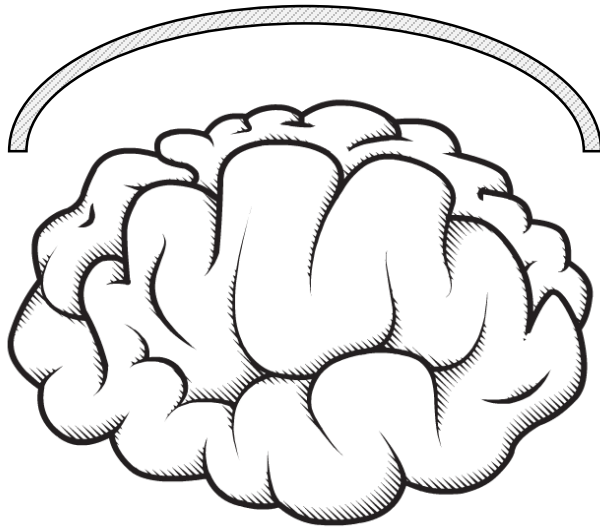


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MT-BCIs, Mental Task-based BCIs

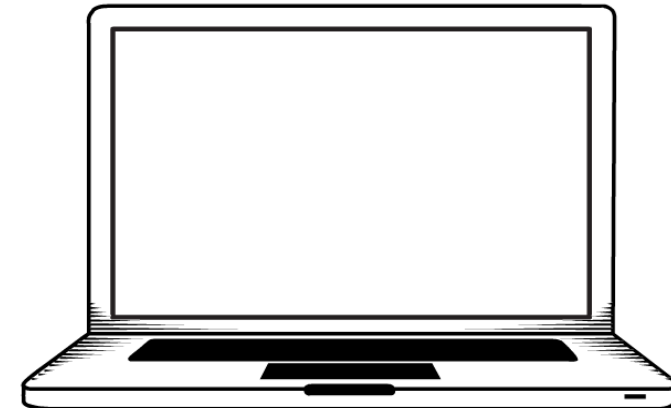
Human /



/ Machine

→
*EEG patterns associated
with a specific mental task*

←
Feedback



For control applications: MT-BCIs to control assistive technologies, video games & many others



[ImmersiveTech @ EPFL “Brain Controlled Wheelchair”]



[Inria Rennes - Project OpenViBE]


Beyond control applications:

Neurofeedback training to improve or recover cognitive / motor abilities

The New York Times

Olympians Use Imagery as Mental Training

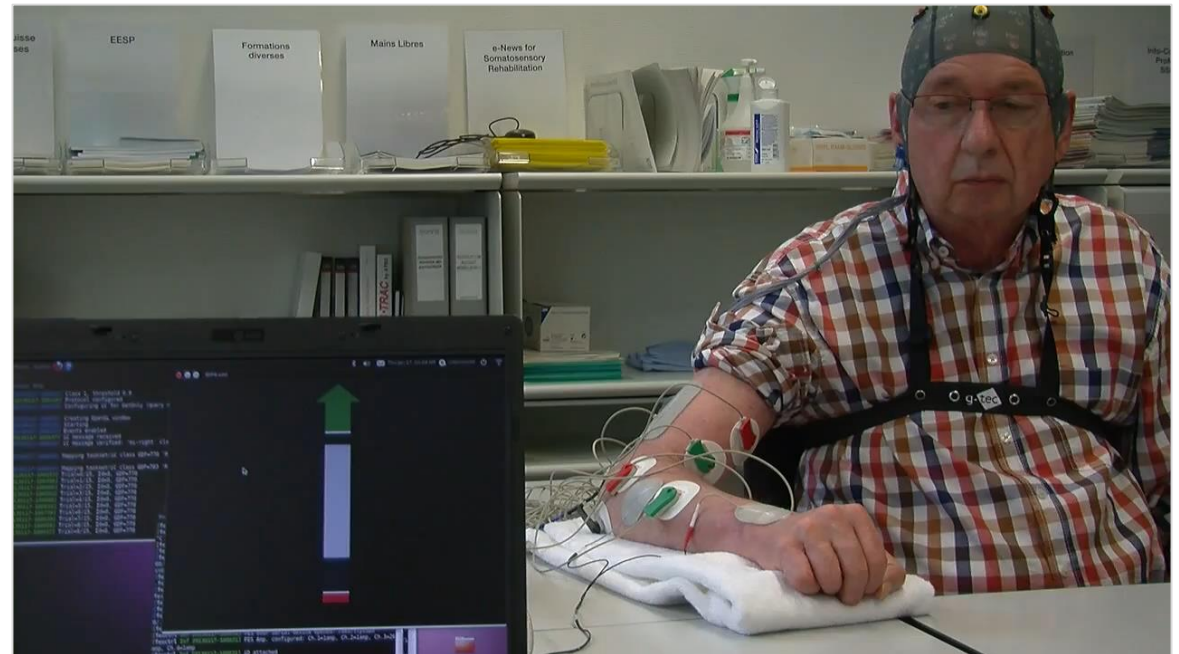
Flying High While Still on the Ground
Nancy Donaldson, Beisel Saget, Joe Ward and Justin Sablich



Emily Cook, of the United States freestyle ski team, visualizes each aerial jump as part of her training for the Olympics. Javier Soriano/Agence France-Presse — Getty Images

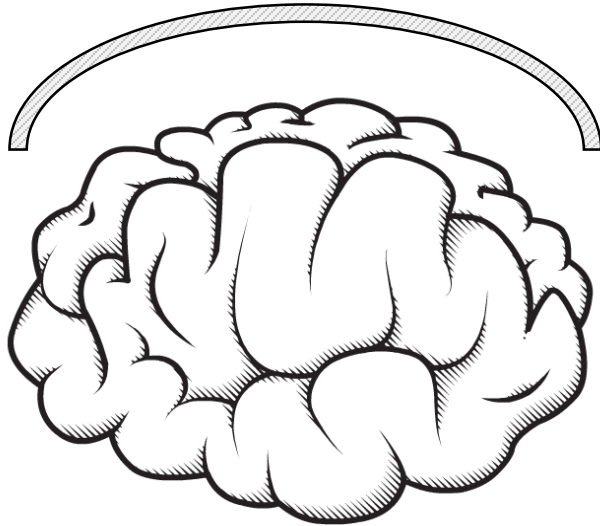
By Christopher Clarey

Feb. 22, 2014



[EPFL News]

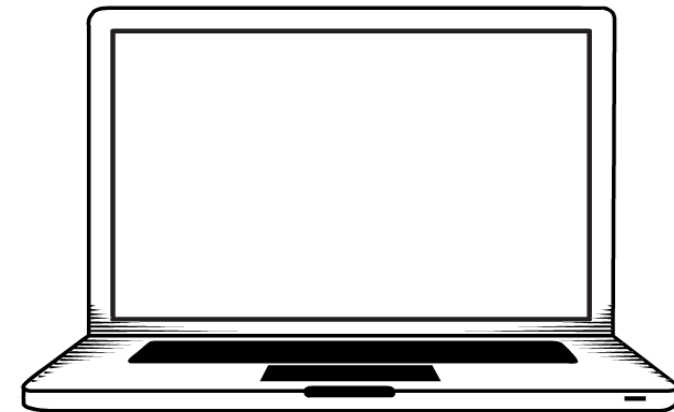
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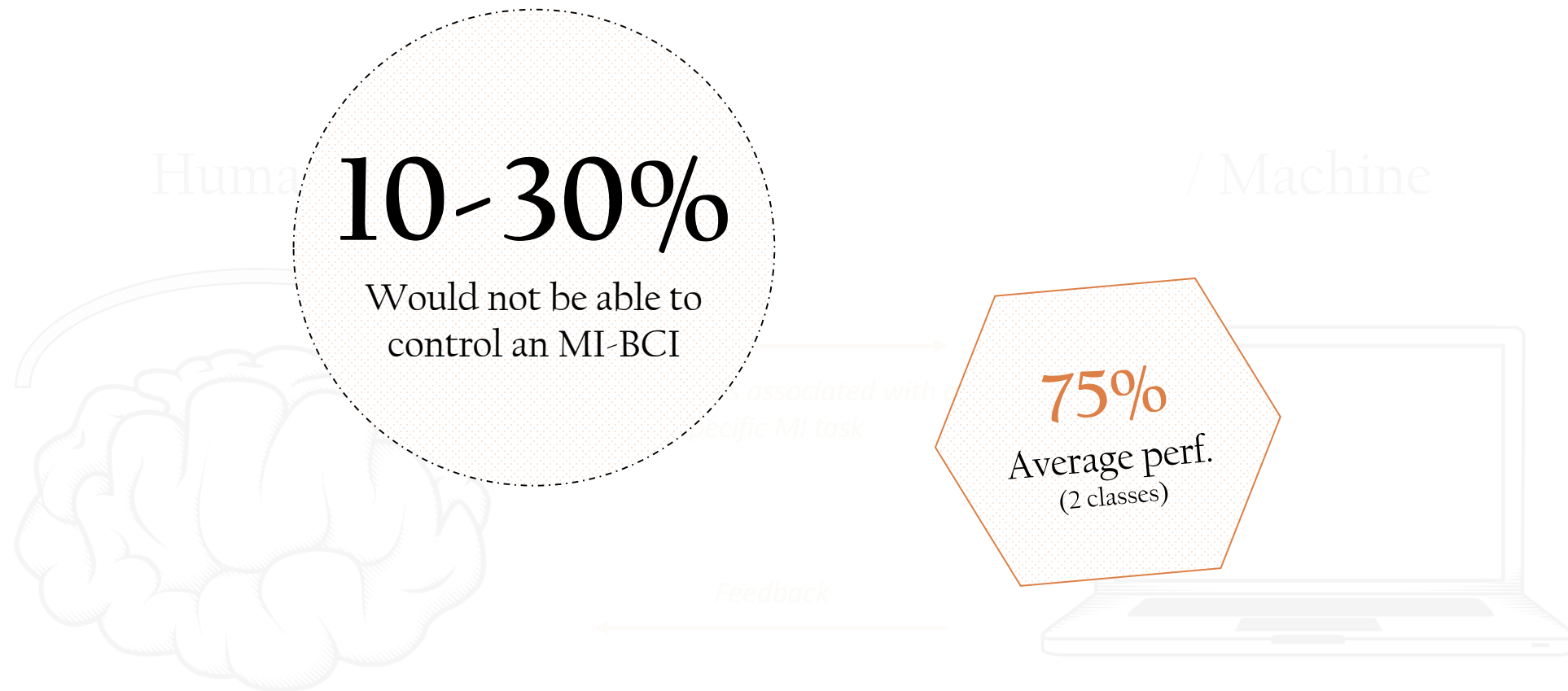
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→
*EEG patterns associated with a
specific MI task*

Feedback
←

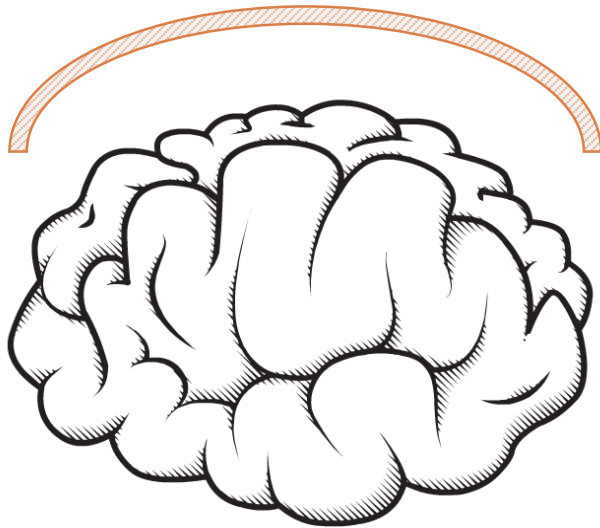


Remain barely used: **reliability issues**



Remain barely used: **reliability issues**

Human /



/ Machine

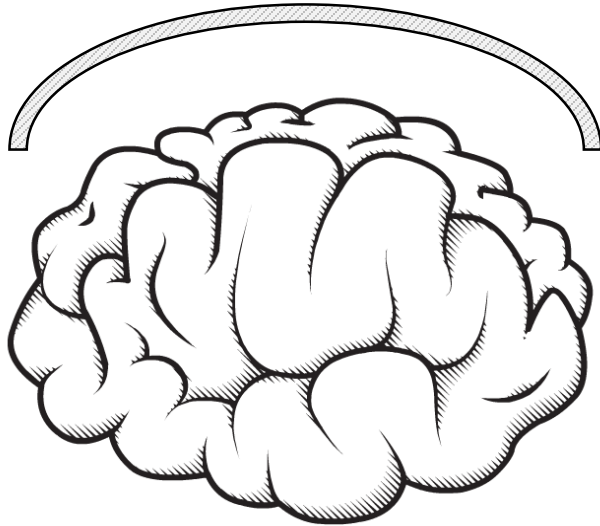
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Remain barely used: **reliability issues**

Human /



/ Machine

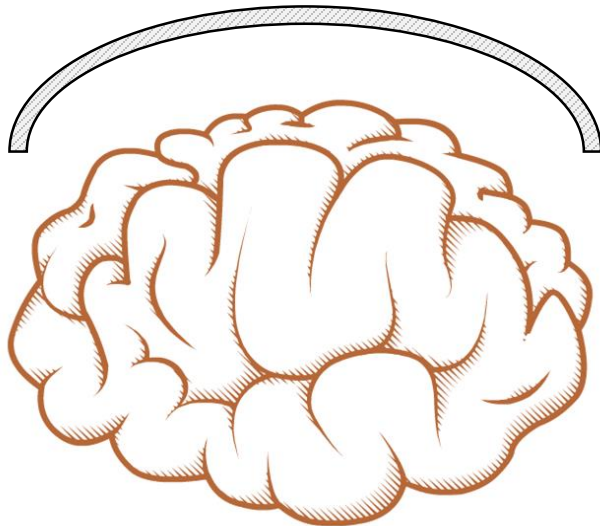
→
*EEG patterns associated with a
specific mental task*

Feedback
←



Remain barely used: **reliability issues**

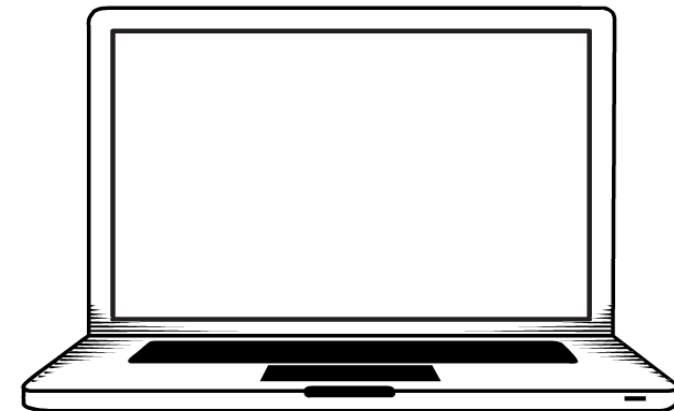
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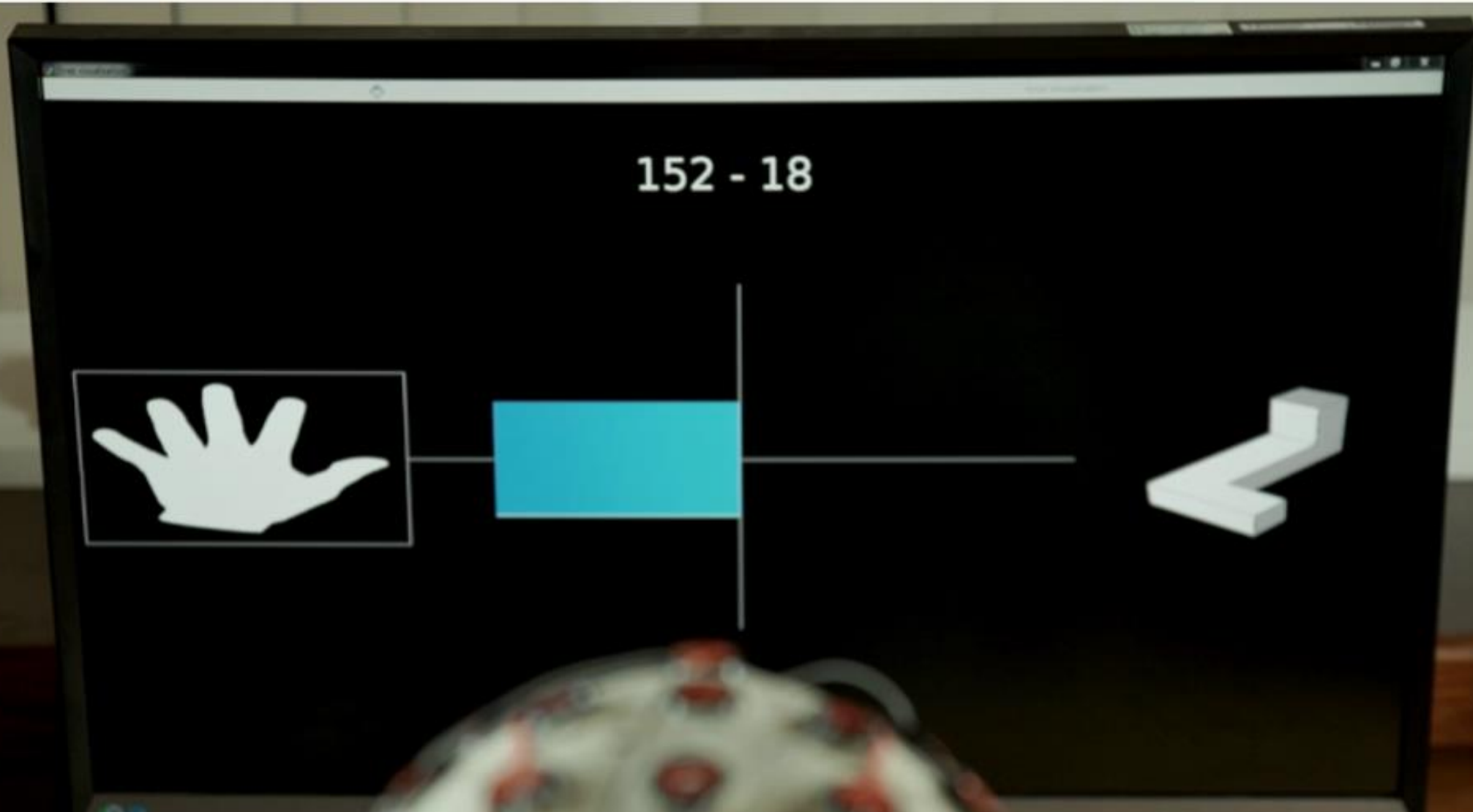


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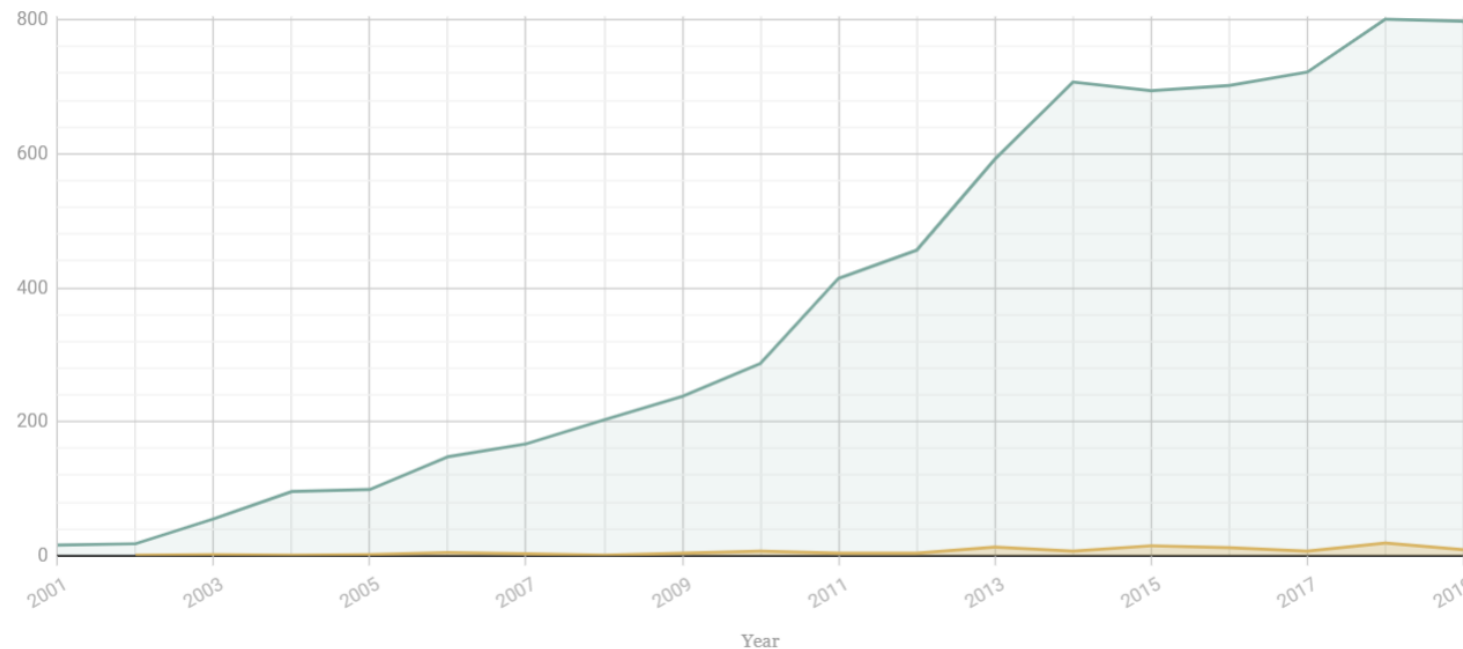


PROBLEM - do not enable MT-BCI users to reach adequate levels of performance

CHALLENGE - improving end-user training

Understanding BCI learning mechanisms and improving end-user training.

Yet, only a very small proportion of BCI research is dedicated to this primordial aspect.



Graph made by **Aline Roc**, representing the number of PubMed entries (including title and abstract) per year for:

● "BCI" [Brain computer interface(s) V brain machine interface(s) V direct neural interface(s)]

● "BCI" & "user learning" [User/human/participant training/learning V user/human/participant profile/trait(s) V learning curve V inefficiency V illiteracy]

Deepen our understanding of MT-BCI learning mechanisms



Design, implement and evaluate innovative MT-BCI training procedures (based on virtual reality and intelligent tutoring systems)



Improve the efficiency and reliability of MT-BCIs



Make MT-BCIs **useful, usable** and actually **used** for real-world, clinical and non-clinical, applications.

Open

Collaborative
International

Intersectoral

Inter-
disciplinary

User-centred
participatory
approach

METHODS

- i. Design a rigorous MT-BCI training procedure based on the literature
- ii. Collect a large database (100+ part., 20 sessions/part.)
- iii. Analyse MT-BCI performance and learning, and their determinants
- iv. Propose innovative and efficient training procedures (VR, ITS)
- v. Apply in real-world applications

Deepen our understanding of MT-BCI learning mechanisms



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Consortium



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Graz Univ. of Technology
Univ. Vienna

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THE NETHERLANDS

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Donders' Institute

Stefanie Enriquez-Geppert
Michael Tangermann

UNITED KINGDOM

Univ. Essex
Univ. Glasgow
Univ. Ulster

Reinhold Scherer, Simis Perdikis
Aleksandra Vuckovic
Damien Coyle

We are happy
to welcome new
collaborations !



METHODS

- i. **Design a rigorous MT-BCI training procedure based on the literature**
- ii. Collect a large database (100+ part., 20 sessions/part.)
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Consultation of the consortium:

- . Which research questions would each member of the consortium like to tackle through the shared protocol?
- . Rating of each question by each member of the consortium
- . Ranking of the questions

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SUMMARY OF THE HIGHLIGHTED RESEARCH QUESTIONS: AVERAGE RATING, RATING DISTRIBUTION & PRIORISATION

Reminder: 1= priority ; 2 = interesting to consider, if possible ; 3 = cannot/should no be tackled in this protocol ; 4 = already (partially) answered or not relevant
 Red = questions rated as a priority ; Blue = questions rated as less relevant or not a priority for this protocol

		MEAN	STD	Number of votes for each rating value:
---- USER LEARNING ---- (NF/BCI dose-response curve)		1,00	0,00	
What does the NF/BCI dose-response curve look like?		1,06	0,24	
How stable is performance within and between sessions?		1,32	0,58	
Does "BCI-illiteracy" really exist if we train the subjects long enough?		2,11	0,88	
How do ERD/ERS evolve with training, as a function of performance and progression?		1,53	0,77	
How could learning outcome be predicted? How many channels are needed?		1,74	0,73	
---- COGNITIVE STRATEGIES ---- (mental imagery strategies)		1,58	0,67	
How do mental-imagery strategies relate to NF/BCI performance and learning success?		1,16	0,37	
Can they be used to predict/explain future performance?		2,21	0,85	
Do they influence the degree of lateralisation of measured EEG activity?		2,79	0,98	

METHODS

- i. **Design a rigorous MT-BCI training procedure based on the literature**
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Consultation of the consortium:

- . Which research questions would each member of the consortium like to tackle through the shared protocol?
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- . Ranking of the questions
- . Identification of the protocol requirements so that the most important questions can be rigorously investigated

METHODS

- i. Design a rigorous MT-BCI training procedure based on the literature
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Identification of design requirements as a function of the different questions, rated as "first-order" and "second-order" priorities

FIRST-ORDER QUESTIONS			Requirements regarding the design to investigate this question	Design Specifications
---- USER LEARNING ---- (NF/BCI dose-response curve)				
1	What does the NF/BCI dose-response curve look like?	1,06	. Large number of sessions	. N-sessions = ~10 with 2 sessions per week (survey : 20 sessions = ok for half, too high for half)
2	How stable is performance within and between sessions?	1,32	. Large number of sessions, and runs / session	. N-runs/session = total duration of the BCI training: ~45-60min
4	How do ERD/ERS evolve with training, as a function of performance and progression?	1,53	. Performance and progression metrics	. Offline analyses
5	How could learning outcome be predicted? How many channels are needed?	1,74	. "Predicting factors"	. Offline analyses
---- COGNITIVE STRATEGIES ---- (mental imagery strategies)				
6	How do mental-imagery strategies relate to NF/BCI performance and learning success?	1,16	. Record / Collect mental strategies	. Phenomenological interviews, at the beginning and end of the training procedure? + Frequent video recordings & verbalisation of the strategies (random experiment sampling?)
...				
SECOND-ORDER QUESTIONS			Can be answered through the design chosen to answer the first-order questions:	Should we modify the design to investigate specifically this question? If yes, how?
---- USER LEARNING ---- (NF/BCI dose-response curve)				
3	Does "BCI-illiteracy" really exist if we train the subjects long enough?	2,11	. YES (large number of sessions - Q1 & Q2)	-
---- COGNITIVE STRATEGIES ---- (mental imagery strategies)				
7	Can they be used to predict/explain future performance?	2,21	. YES (the cognitive strategies are collected - Q6)	-
8	Do they influence the degree of lateralisation of measured EEG activity?	2,79	. YES (the cognitive strategies are collected - Q6) . But specific to motor imagery	-

METHODS

- i. **Design a rigorous MT-BCI training procedure based on the literature**
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- . Identification of the protocol requirements so that the most important questions can be rigorously investigated

Constitution of a design group and thematic subgroups:

- . Based on the general outline of the protocol, we are now working on assessment (**A. Kübler***), instructions (**S. Enriquez-Geppert***), machine learning (**R. Scherer***), interface (**F. Lotte***) and transfer (**D. Coyle***) aspects of the protocol.

METHODS

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WE NEED SUPPORT:

- . To strengthen our consortium still further
- . To implement the protocol and open database
- . To include participants in all the partners' labs
- . To analyse the data and extract from them innovative research avenues in terms of MT-BCI training procedures
- . To foster international, interdisciplinary and intersectoral collaborations
- . To transfer this new and indispensable knowledge to real-world applications and promote MT-BCI technologies



Thank you!



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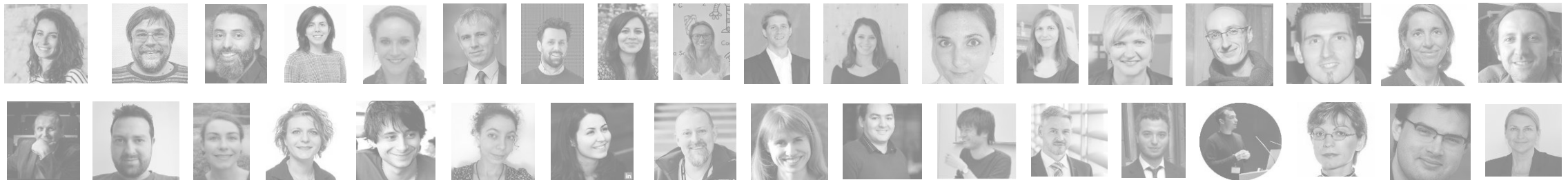
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MAJOR CHALLENGE

Collaborating using an **open-science** and **interdisciplinary** approach in order to deepen our understanding of **MT-BCI user learning mechanisms** and to design **innovative and efficient training procedures**.

This step is essential for BCIs to be **useful, usable and actually used** out-of-the-lab, both for clinical and non-clinical applications.



SUMMARY OF THE HIGHLIGHTED RESEARCH QUESTIONS: AVERAGE RATING, RATING DISTRIBUTION & PRIORISATION

Reminder: 1= priority; 2 = interesting to consider, if possible ; 3 = cannot/should no be tackled in this protocol ; 4 = already (partially) answered or not relevant
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---- COGNITIVE STRATEGIES ---- (mental imagery strategies)		1,58	0,67	
How do mental-imagery strategies relate to NF/BCI performance and learning success?		1,16	0,37	
Can they be used to predict/explain future performance?		2,21	0,85	
Do they influence the degree of lateralisation of measured EEG activity?		2,79	0,98	
Do MI strategies (and underlying EEG features) relate to the states of the user?		1,89	0,74	
Can BCI operation automatise? (i.e., proceduralisation)		2,32	0,82	

---- USER PROFILE ---- (demographical, psycho, cog & neurophy factors)		1,33	0,49	
How does the user profile relate to BCI/NF performance?		1,53	0,70	
Does it (partly) explain between-subject variations in terms of performance and learning abilities?		1,47	0,70	
---- MACHINE LEARNING ----(decoder/classifier/performance metrics)		2,17	0,58	
Is it more relevant/efficient to fixate the classifier or to regularly update it?		2,06	0,73	
Are classifiers actually efficient to favour learning? How to ensure that they are?		1,89	0,76	
Are the classifier's features robust to variations of the user's state (fatigue, workload)?		2,28	0,67	
How to design/train decoders that are stable across subjects and sessions?		1,72	0,57	
How, when, how often to retrain the classifier? (stability/flexibility tradeoff, coadaptation)		2,39	0,61	
What are the most suitable metrics for characterising BCI/NF performance and skill acquisition?		1,39	0,50	
Would transfer-learning approaches enable a faster user learning?		2,44	0,62	
---- TRAINING PROCEDURE ---- (instructions, tasks, training environment, fb)		1,91	0,70	
Does the design of the training procedure influence BCI/NF performance and learning?		2,00	0,88	
What kind of instructions should be provided?		1,67	0,84	
In there any gain in BCI performance/learning/user-experience from the step-wise approach ?		2,17	0,62	
Do VR/AR-based training environments favour learning?		3,22	0,81	
Is multimodal better than unimodal feedback?		2,89	0,90	

Identification of design requirements as a function of the different questions, rated as "first-order" and "second-order" priorities

FIRST-ORDER QUESTIONS			Requirements regarding the design to investigate this question	Design Specifications
---- USER LEARNING ---- (NF/BCI dose-response curve)				
		1,00		
1	What does the NF/BCI dose-response curve look like?	1,06	. Large number of sessions	. N-sessions = ~10 with 2 sessions per week (survey : 20 sessions = ok for half, too high for half)
2	How stable is performance within and between sessions?	1,32	. Large number of sessions, and runs / session	. N-runs/session = total duration of the BCI training: ~45-60min
4	How do ERD/ERS evolve with training, as a function of performance and progression?	1,53	. Performance and progression metrics	. Offline analyses
5	How could learning outcome be predicted? How many channels are needed?	1,74	. "Predicting factors"	. Offline analyses
---- COGNITIVE STRATEGIES ---- (mental imagery strategies)				
		1,58		
6	How do mental-imagery strategies relate to NF/BCI performance and learning success?	1,16	. Record / Collect mental strategies	. Phenomenological interviews, at the beginning and end of the training procedure? + Frequent video recordings & verbalisation of the strategies (random experiment sampling?)
---- USER PROFILE ---- (demographical, psychological, cognitive & neurophysiological factors)				
		1,33		
11	How does the user profile relate to BCI/NF performance?	1,53	. Assessment of the user profile	. Psychometric questionnaires : we will use some, to be determined later
12	Does it (partly) explain between-subject variations in terms of performance and learning abilities?	1,47	. Assessment of user traits	. What, when, how? (fatigue, perceived difficulty, ...), also to be determined later
---- MACHINE LEARNING ----(decoder/classifier/performance metrics)				
		2,17		
16	How to design/train decoders that are stable across subjects and sessions?	1,72		. Offline analyses
18	What are the most suitable metrics to characterise BCI/NF performance & skill acquisition?	1,39	. Transfer task at the end > depending on the focus (learning vs	. Transfer task at the end (potentially 2 different ones) + Offline analyses
---- TRAINING PROCEDURE ---- (instructions, tasks, training environment, fb)				
		1,91		
21	What kind of instructions should be provided?	1,67	. Should be exactly the same for all the participants	. Definition of one instruction and translation into 4 languages (english french german italian)

SECOND-ORDER QUESTIONS			Can be answered through the design chosen to answer the first-order questions:	Should we modify the design to investigate specifically this question? If yes, how?
---- USER LEARNING ---- (NF/BCI dose-response curve)		1,00		
3	Does "BCI-illiteracy" really exist if we train the subjects long enough?	2,11	. YES (large number of sessions - Q1 & Q2)	-
---- COGNITIVE STRATEGIES ---- (mental imagery strategies)		1,58		
7	Can they be used to predict/explain future performance?	2,21	. YES (the cognitive strategies are collected - Q6)	-
8	Do they influence the degree of lateralisation of measured EEG activity?	2,79	. YES (the cognitive strategies are collected - Q6) . But specific to motor imagery	-
9	Do MI strategies (and underlying EEG features) relate to the states of the user?	1,89	. YES (te cognitive strategies are collected - Q6, together with the reported users' states - Q12)	-
10	Can BCI operation automatise? (i.e., proceduralisation)	2,32	. YES (the cognitive strategies are collected - Q6)	-
---- USER PROFILE ---- (demographical, psychological, cognitive & neurophysiological factors)		1,33		
---- MACHINE LEARNING ---- (decoder/classifier/performance metrics)		2,17		
13	Is it more relevant/efficient to fixate the classifier or to regularly update it?	2,06	. NO	. NO - it is not the purpose of this experimentation
14	Are classifiers actually efficient to favour learning? How to ensure that they are?	1,89	. NO	. NO - it is not the purpose of this experimentation
15	Are the classifier's features robust to variations of the user's state (fatigue, workload)?	2,28	. PARTIALLY - As we will regularly assess the users' states (Q12), we might be able to answer this question for the specific classifier that we will use	-
17	How, when, how often to retrain the classifier? (stability/flexibility tradeoff, coadaptation)	2,39	. NO	. NO - it is not the purpose of this experimentation
19	Would transfer-learning approaches enable a faster user learning?	2,44	. NO	. NO - it is not the purpose of this experimentation
---- TRAINING PROCEDURE ---- (instructions, tasks, training environment, fb)		1,91		
20	Does the design of the training procedure influence BCI/NF performance and learning?	2,00	. NO	. NO - Would require 2 groups - as the most important question is about the learning (and not about proving that one design is better than another) we will not investigate this question
22	Is there any gain in BCI performance/learning/user-experience from the step-wise approach ?	2,17	. NO	. NO - Would require a control group, not the main object (+ it would be too difficult to design the protocol for the control group)
23	Do VR/AR-based training environments favour learning?	3,22	. NO	. NO - it is not the purpose of this experimentation- too specific
24	Is multimodal better than unimodal feedback?	2,89	. NO	. NO - it is not the purpose of this experimentation- too specific